Design Considerations of Polishing Lap for Computer-Controlled Cylindrical Polishing Process

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Motivation

- Requirement for grazing-incidence x-ray shell optics with angular resolution of < 5 arcsec HPD.

  Typical mirror shells fabricated to date at MSFC have HPDs in 13-15 arcsec range.

  Achievable resolution depends on the quality of the mandrels from which the mirror shells are replicated.

  Mid spatial-frequency range errors on the mandrel surface are currently limiting the quality of the mandrel

- Therefore, deterministic and localised polishing of the mandrel is desirable

Abstract

- Simulation studies on cylindrical polishing process
  - Establishing a relationship between the polishing process parameters and the generation of mid spatial-frequency error
  - Optimization of the process (speeds, stroke, etc.) to keep the residual mid spatial-frequency error to a minimum
  - Consideration of the polishing lap design to optimize the process in order to keep residual errors to a minimum
- Development of a computer-controlled polishing machine

Cylindrical polishing

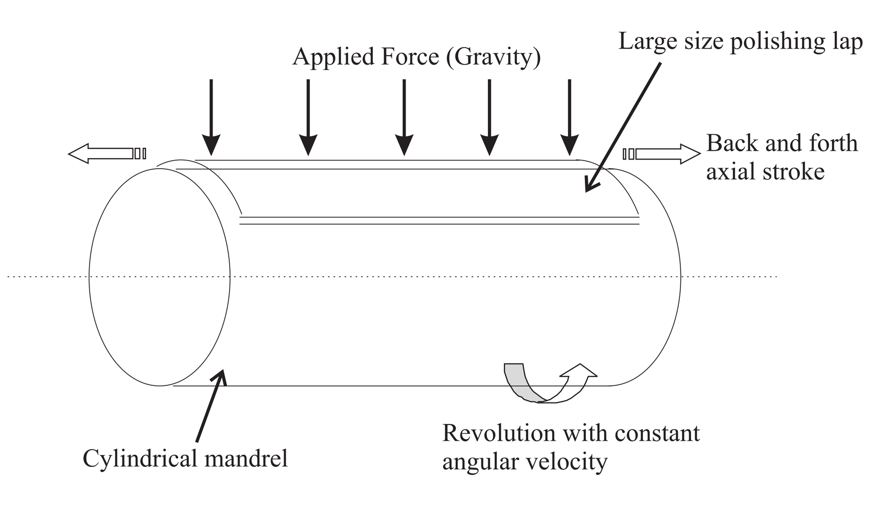

Fig. 1. Kinematics of a typical large area cylindrical polishing process

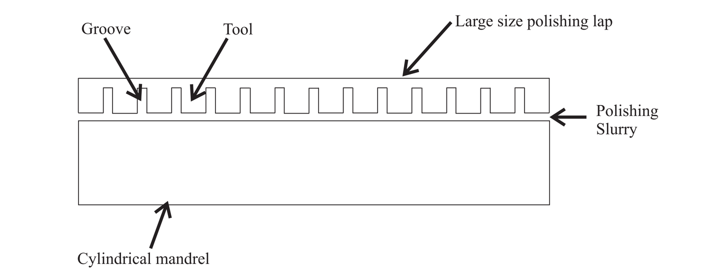

Fig. 2. Schematic of a typical polishing lap in contact with the surface to be polished

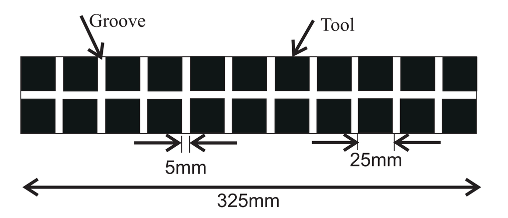

Fig. 3. Top view of the lap showing the distribution scheme of tools

- Operating parameters

  Axial speed of the back and forth polishing lap motion (stroke of the lap)

  Rotational speed of the mandrel

  Length of the stroke

- Design considerations for the polishing lap

  Relation between the rotational speed and the stroke length for the lap

  Relation between the stroke length and the tool size

  Effects of tool-to-groove ratio and distribution of the tool over the lap surface

Simulation Studies

- Performance evaluation

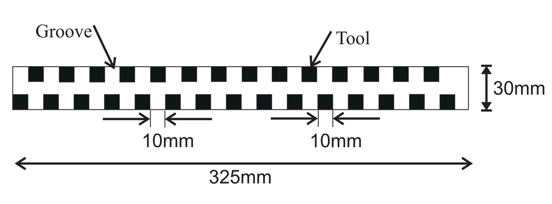

Fig. 4. Top view of the lap showing the distribution scheme of the tools. The tools positions in two rows are shifted. The tool size is 10 mm.

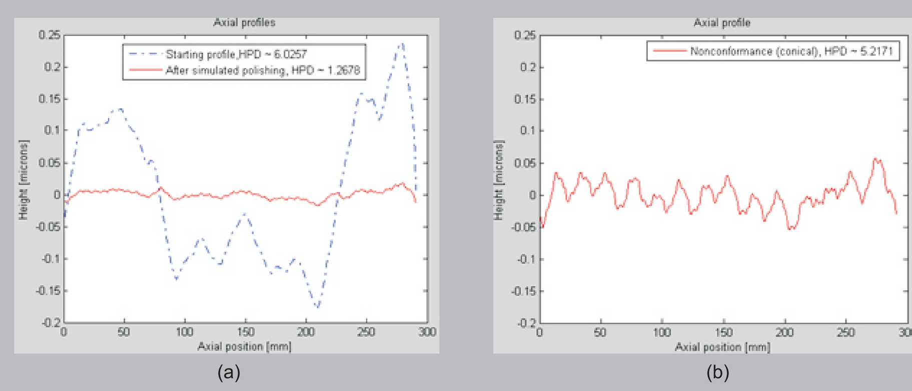

Fig. 5. Achievable axial profile errors after polishing simulations for cylindrical surfaces; a) where nonconformance errors are not present b) where nonconformance errors are present

- Effects of Influence function

Symmetric Influence function

Three different Gaussian shaped influence functions

Different material removal capacity

The study suggest that the closer the influence function is to uniform material removal, the better the achievable HPD is.

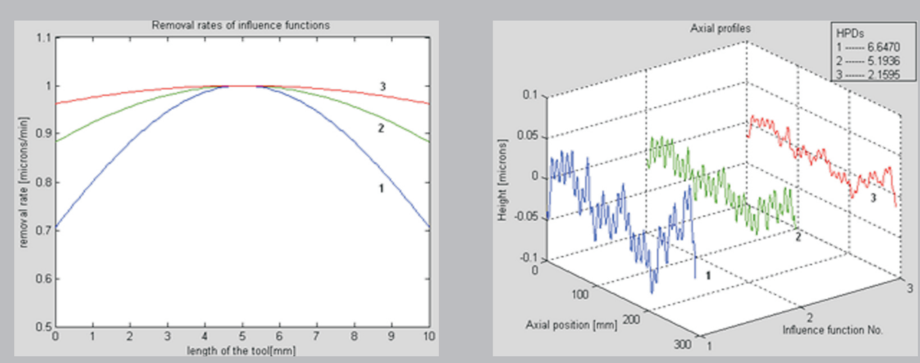

Fig. 6. a) Influence functions with Gaussian shaped removal rates, b) Axial residual error profiles corresponding to influence functions

Asymmetric Influence function

Edge dependent influence function

Different influence in forward and backward stroke direction

The study suggests that the more symmetric an influence function, the higher is the achievable surface quality.

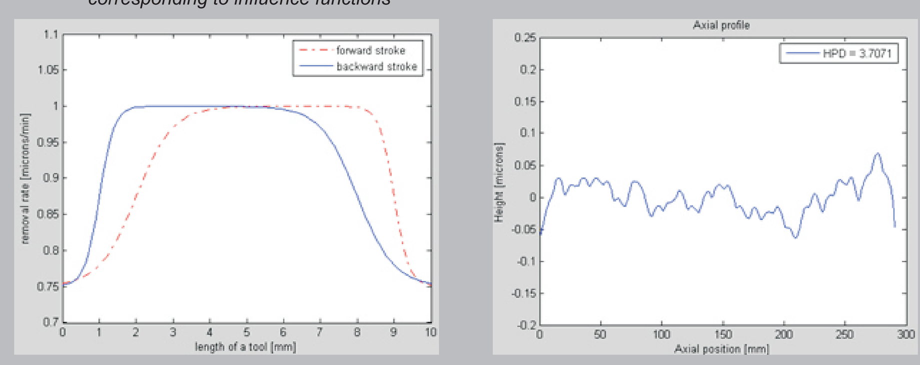

Fig. 7. a) Edge dependent Asymmetric influence function in forward and backward direction, b) Axial residual error profiles corresponding to the influence function

Status of the experiment

- Salient features of the polishing machine

  Accommodates specimen of length from 12 to 30 inches with diameter ranging from 1.5 to 12 inches,

  In order to keep uniform pressure distribution on the optical surface, a floating lap is used,

  Applied pressure on the lap can be varied by the addition of weights,

  Cog-free linear motor is employed to avoid vibration during polishing stroke,

  Linear scale feedback system with 10µm feedback resolution,

  Straightness of 2.5 µm in axial motion.

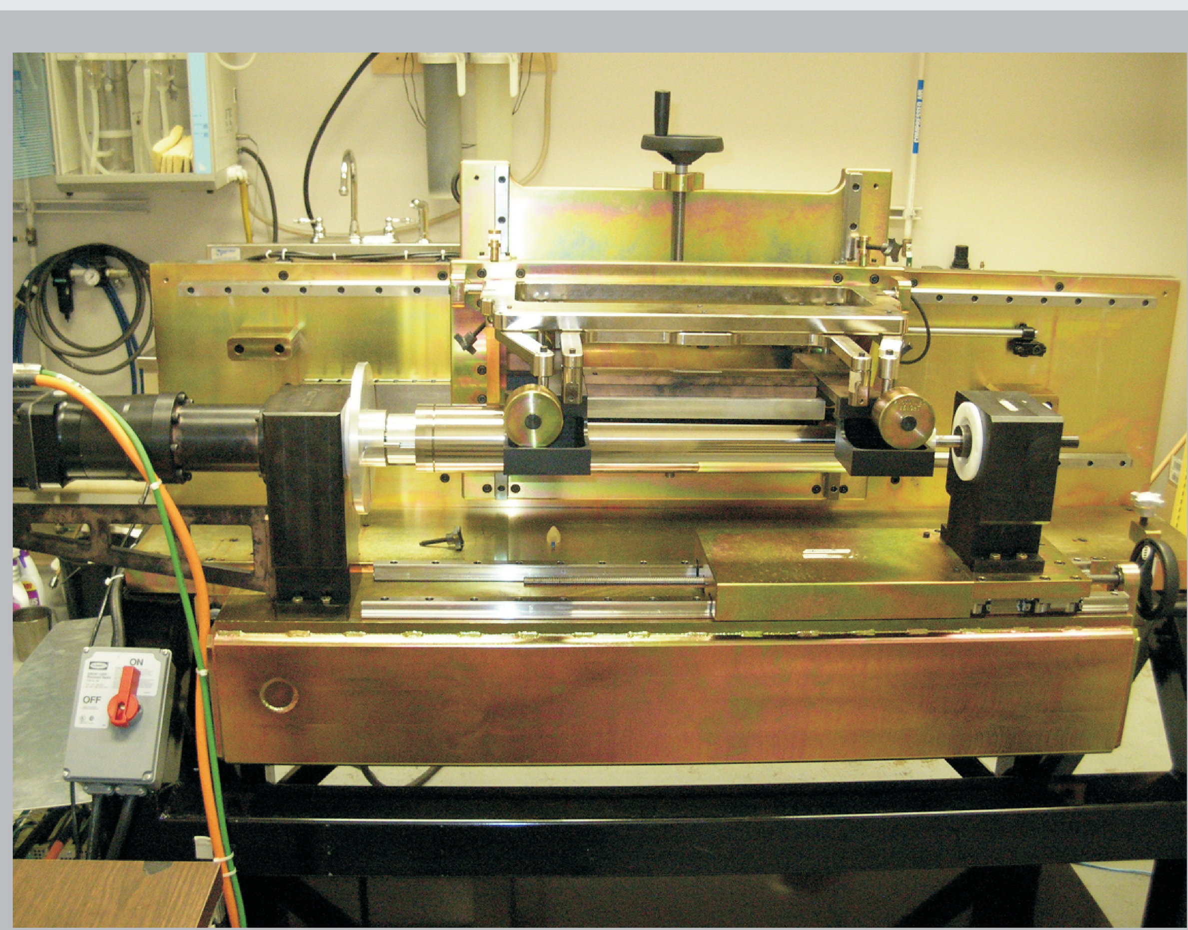

Fig. 8. Computer controlled polishing machine for deterministic and localized polishing of cylindrical mandrels.

Conclusions

Ability to simulate the polishing process is an important contribution to extend automation further and thus increase cost effectiveness.

It is expected that the study will help us bring the angular resolution of the final electroformed shell optics close to the 5 arcsec HPD goal.

Literature

[1] See http://ixo.gsfc.nasa.gov/science/performanceRequirements.html

[2] B. D. Ramsey, “Replicated nickel optics for the hard-x-ray region”, Experimental Astronomy 20 (2005) 85-92

[3] Mikhail Gubarev, Brian Ramsey, Darell Engelhaupt, William Arnold, “Technology Development for Nickel X-Ray Optics Enhancement” Proc SPIE XXXX 2008

[4] F W Preston“The Theory and Design of Plate Glass Polishing”, Journal of the Society of Glass Technology 11 (1927) 214-256